Accounting for the variability of soil hydraulic properties in soil water regime estimation of intensively tilled soils

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NORSK INSTITUTT FOR BIOØKONOMI

Csilla Farkas
Symposium – SWAP 50 years

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- Objectives
- Experimental site
- Soil hydraulic functions
- Soil water content dynamics
- Applying the SWAP model
- Climate scenarios
- Conclusions

tillage practices

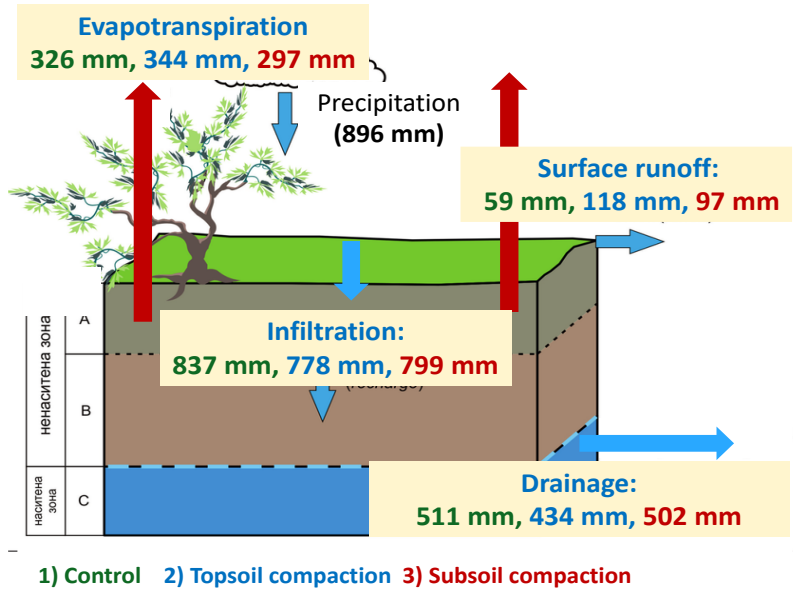
conventional | conservation | no-till

Problems

- Extreme soil water regime in the region (water ponding and drought within the same vegetation season)
- Soil structural degradation
- Maintaining favourable soil water regime and sustainable crop production under changing conditions

Objectives

- To study the effect of conventional and soil-conserving tillage systems on soil properties and water regime
- To examine the seasonal variability of soil hydraulic properties of tilled soil
- To evaluate the soil water regime under present and future conditions



Sustainable agricultural management

information on the

effect of various management practices on

soil water regime and crop yield

complex approach

field and lab measurements

monitoring

mathematical modelling

Experimental setup and measurements

Experimental site and soil type	Years	Crop	Treatments	Measured properties in 2003	frequency
Józsefmajor, Hungary **long-term tillage experiment** **Mollisol**	**2002**	**wheat**	**NT** - no tillage **P** - ploughing (22-25 cm) **D** - disking (16-22 cm)	**bd** - bulk density **Θ(h)** - water retention curve **Ksa**t - saturated hydraulic conductivity	8 times during the vegetation season, from undisturbed soil cores
	2003	**corn**	**LD - L*** (40-45 cm) + **D** (16-22 cm) **S -** (12-15 cm) shallow cultivator **C -** (20-22 cm) deep cultivator	**K(Θ)** - hydraulic conductivity function **Θ(t)** - soil water content dynamics biological activity indicators	5 times in situ continous monthly

* **L**- deep loosening

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Determination of soil hydraulic conductivity function – I.

- **Saturated hydraulic conductivity:**

  double-ring infiltrometer

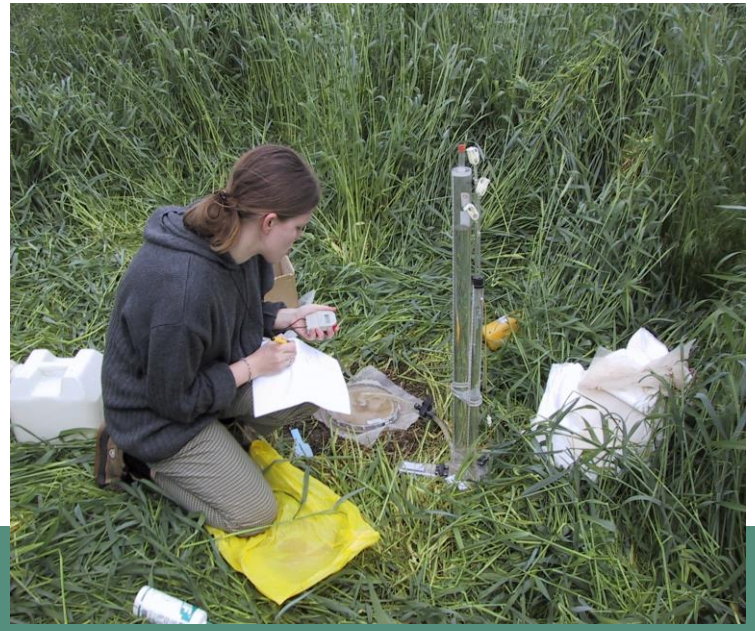
Determination of soil hydraulic conductivity function – II.

- **Saturated hydraulic conductivity:**

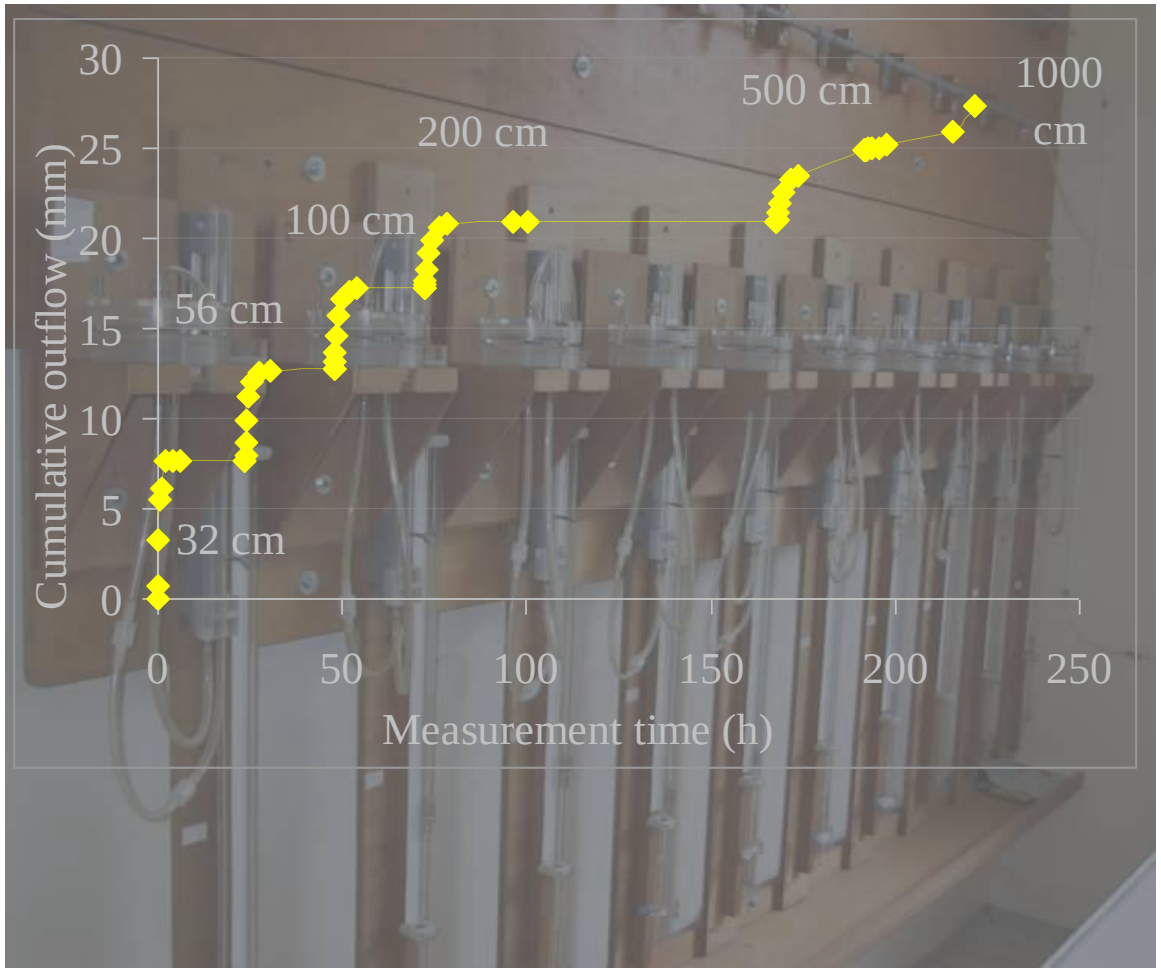
  double-ring infiltrometer

- **Near - saturated hydraulic conductivity:**

  tension disc infiltrometer



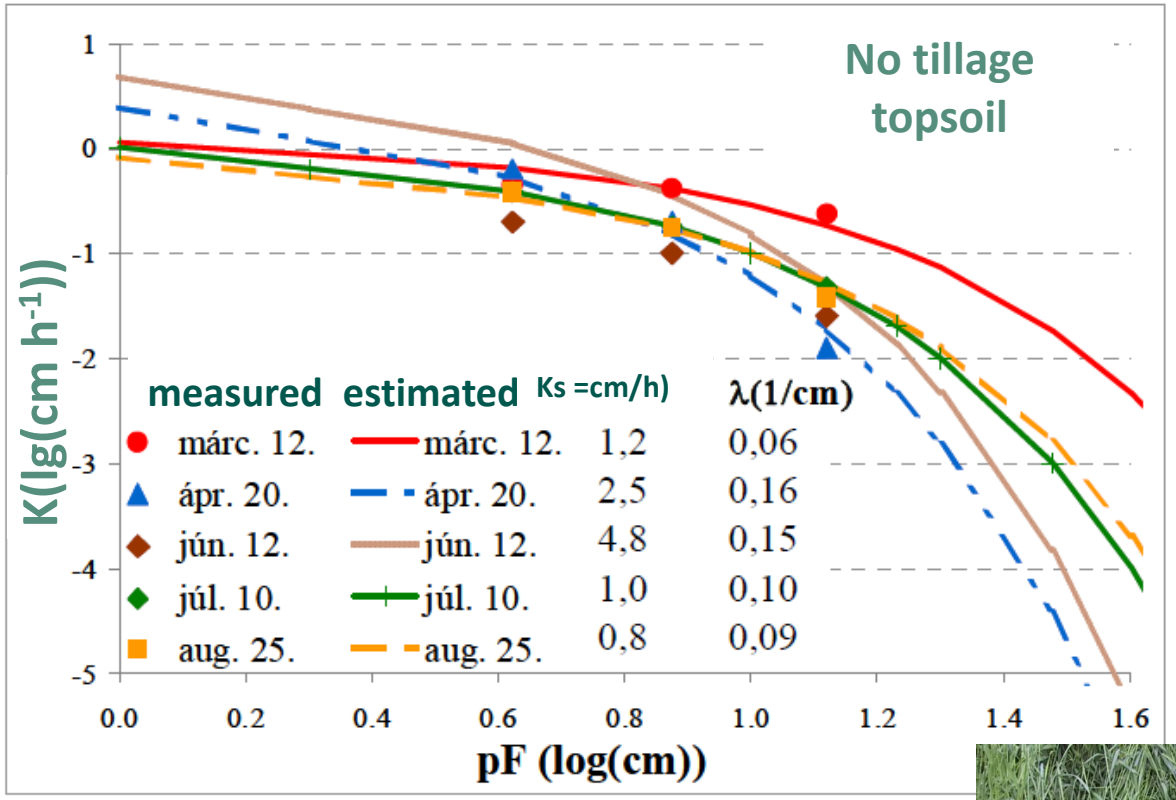
Determination of soil hydraulic conductivity function – III.

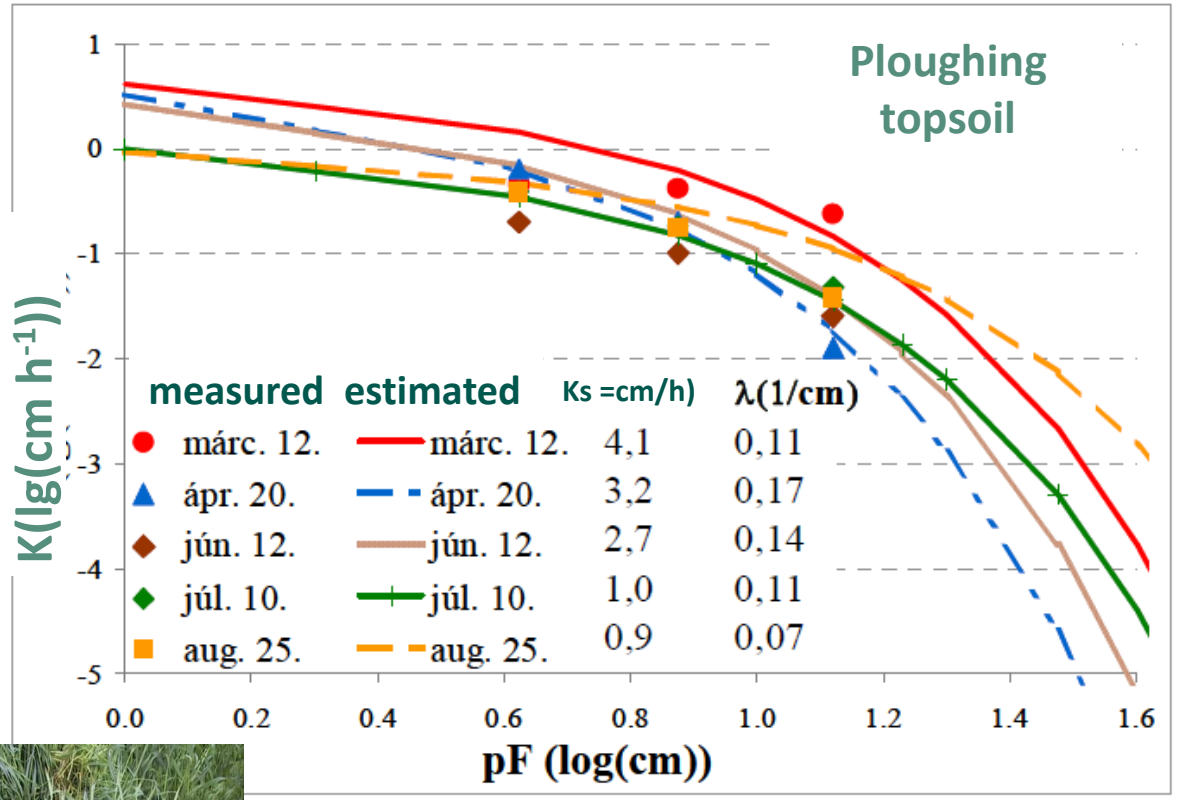


- **Hydraulic conductivity function** -

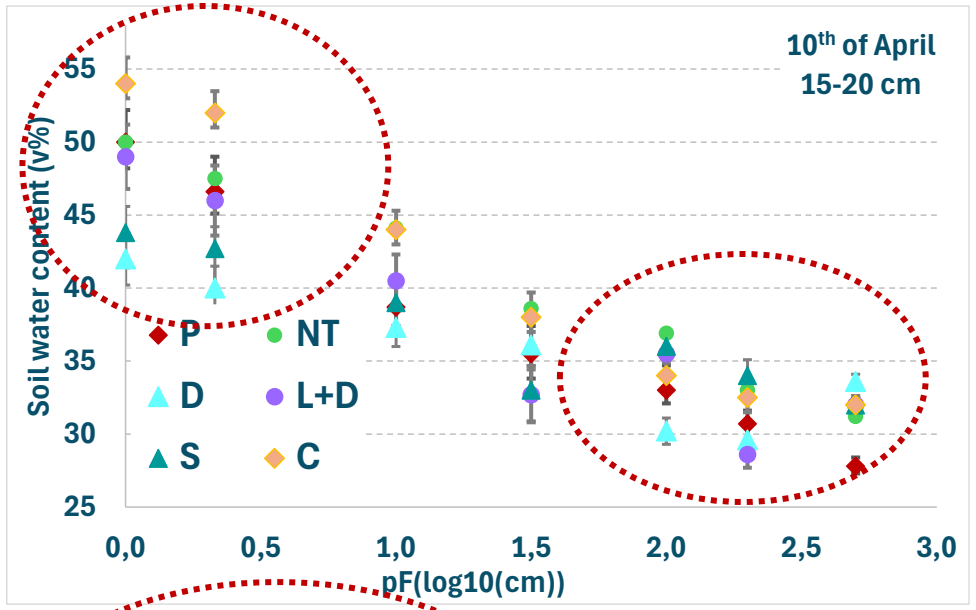
  multistep outflow equipment

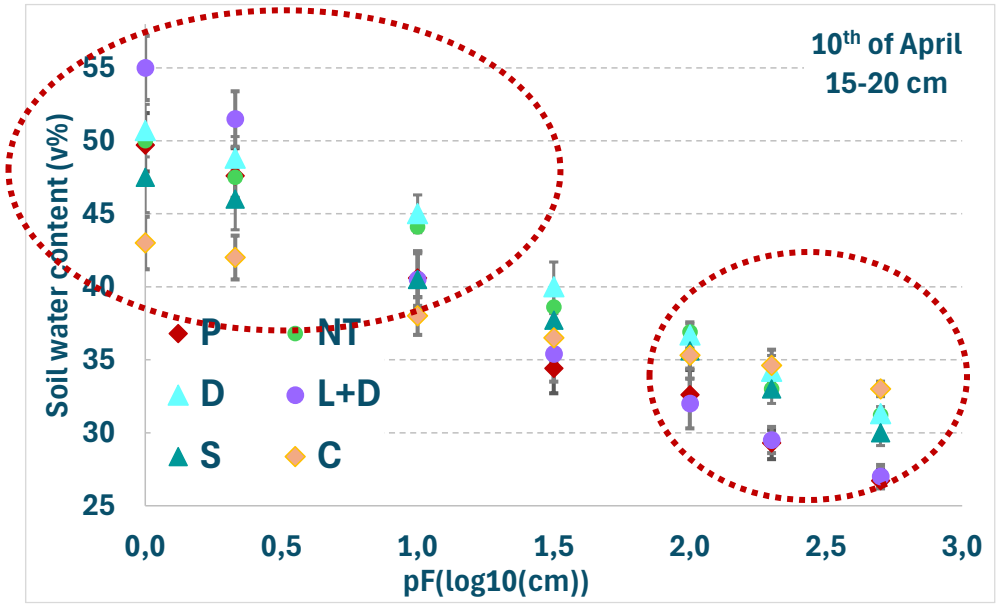
Temporal changes of the soil hydraulic conductivity functions

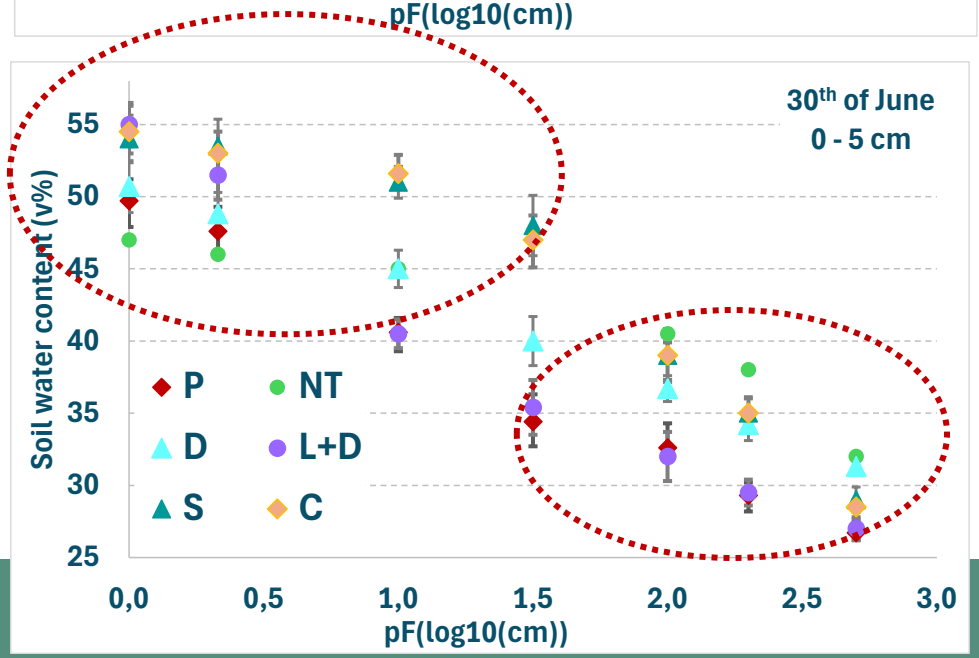


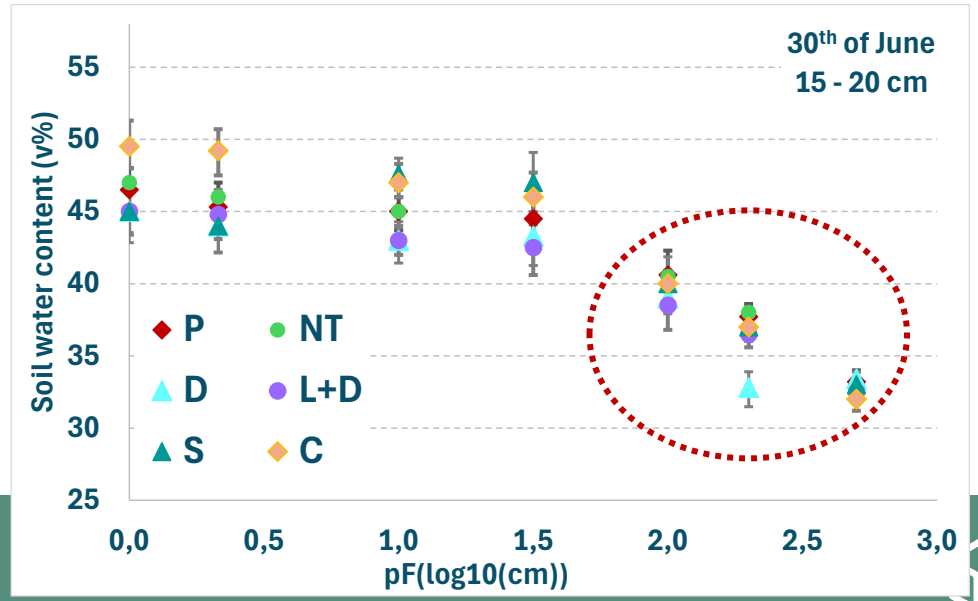


Soil water retention curves measured in different tillage treatments









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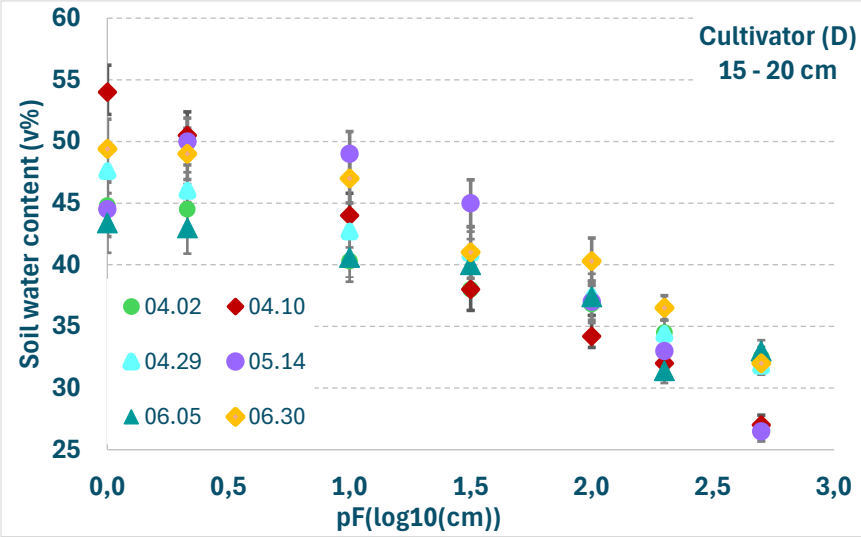
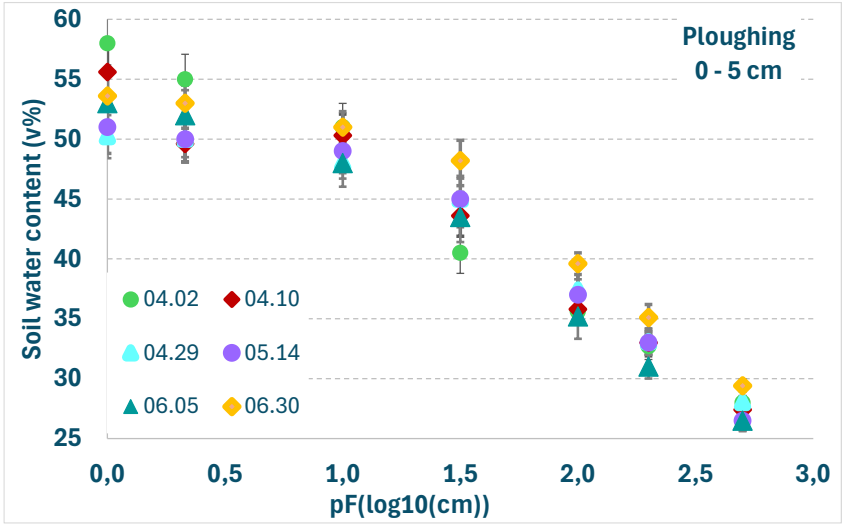
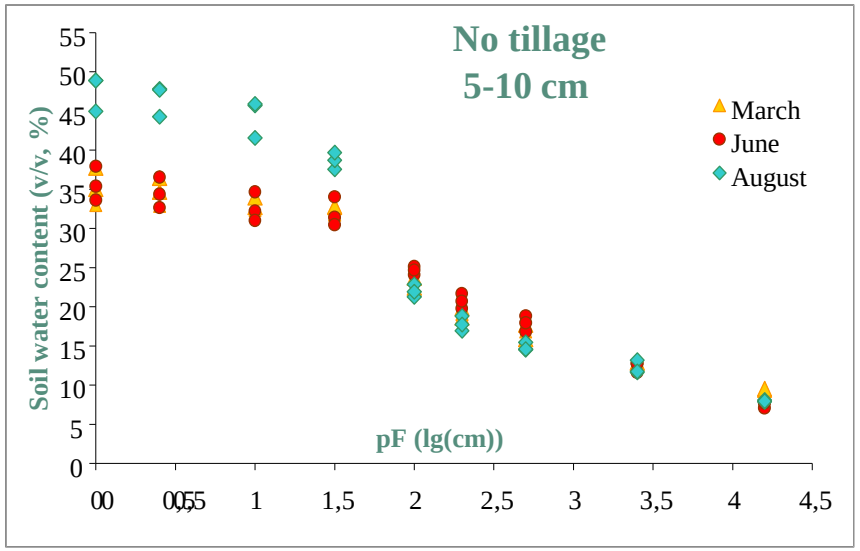
Seasonal changes in soil water retention curves in different tillage treatments



Key processes

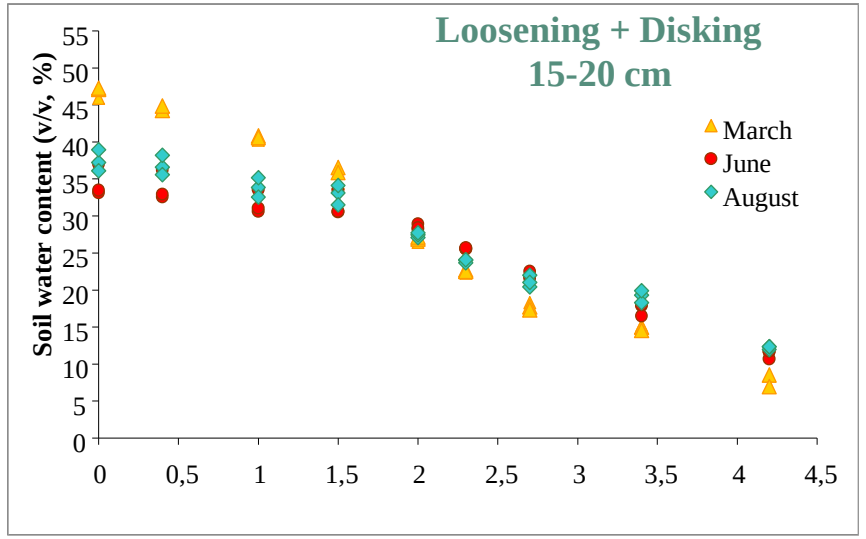
- Natural consolidation
- Intensive loosening – tillage
- Compaction – tillage
- Consolidation
- Biological activity



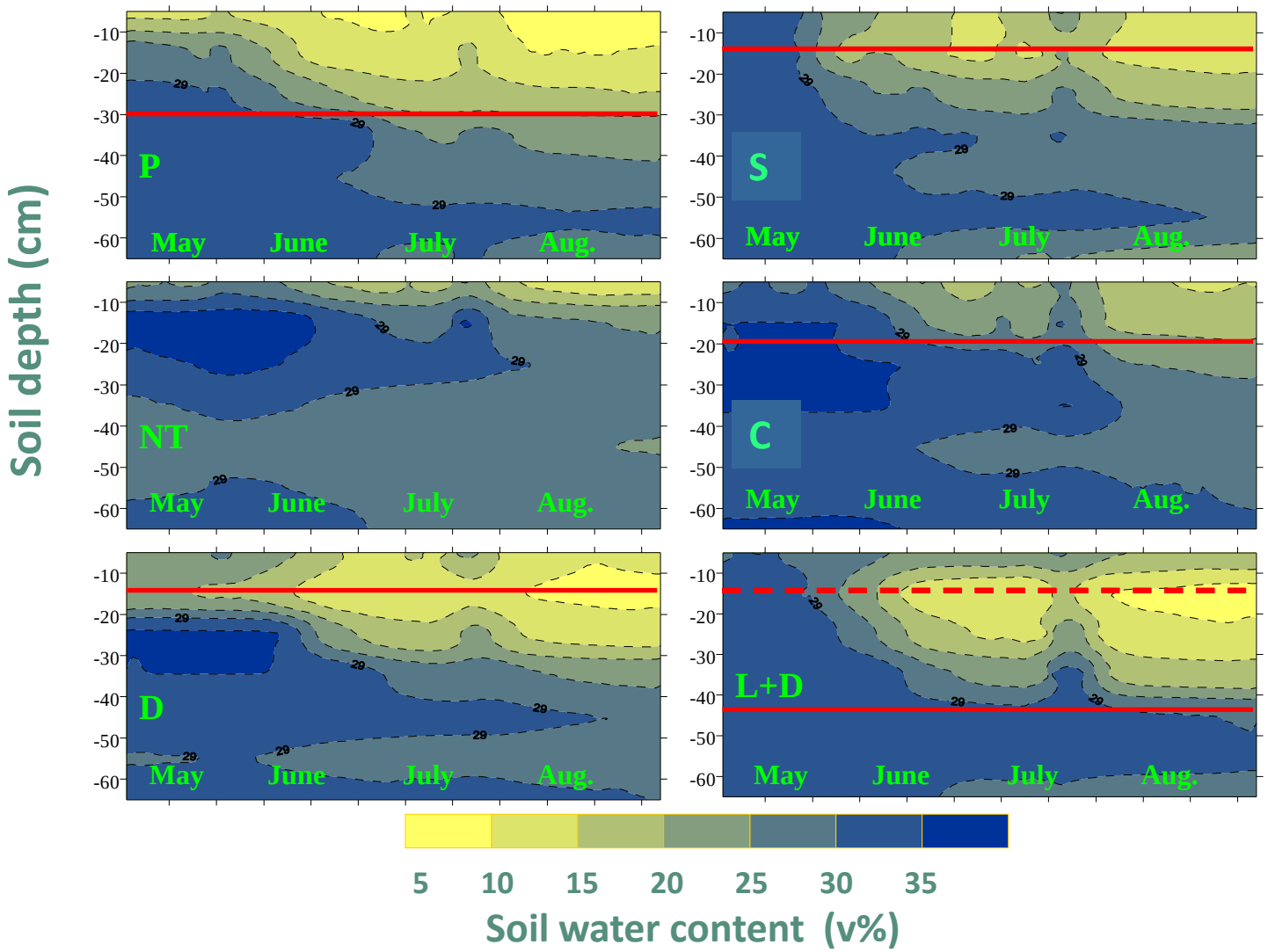


Factors

- Level of soil disturbance
- Type of tillage
- Depth of tillage
- Soil structural stability
- Biological activity
- ...



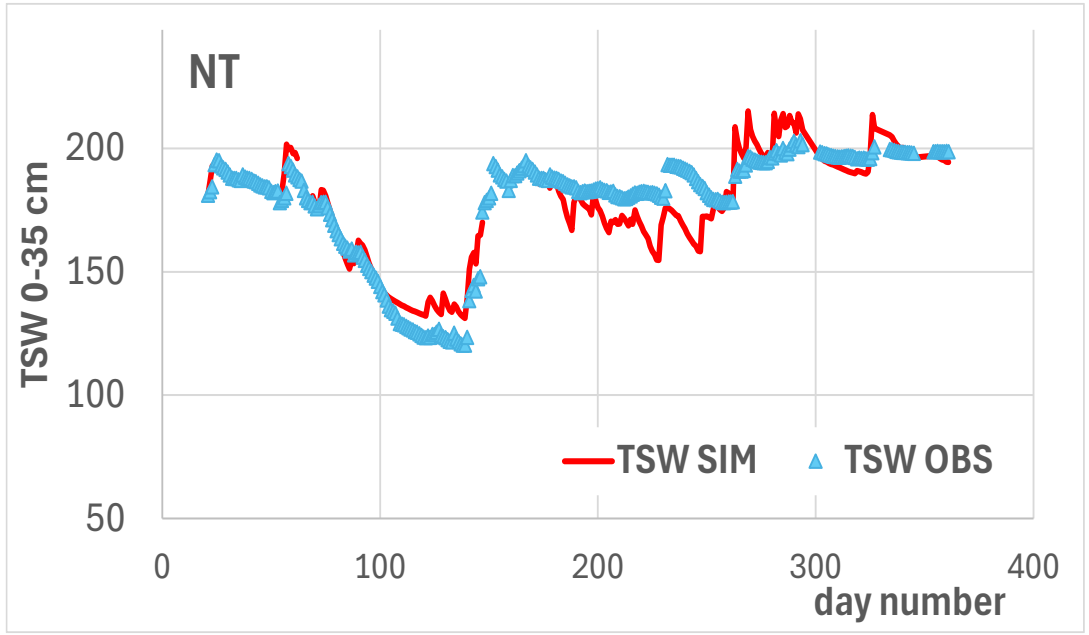
Soil water content dynamics in the different tillage systems



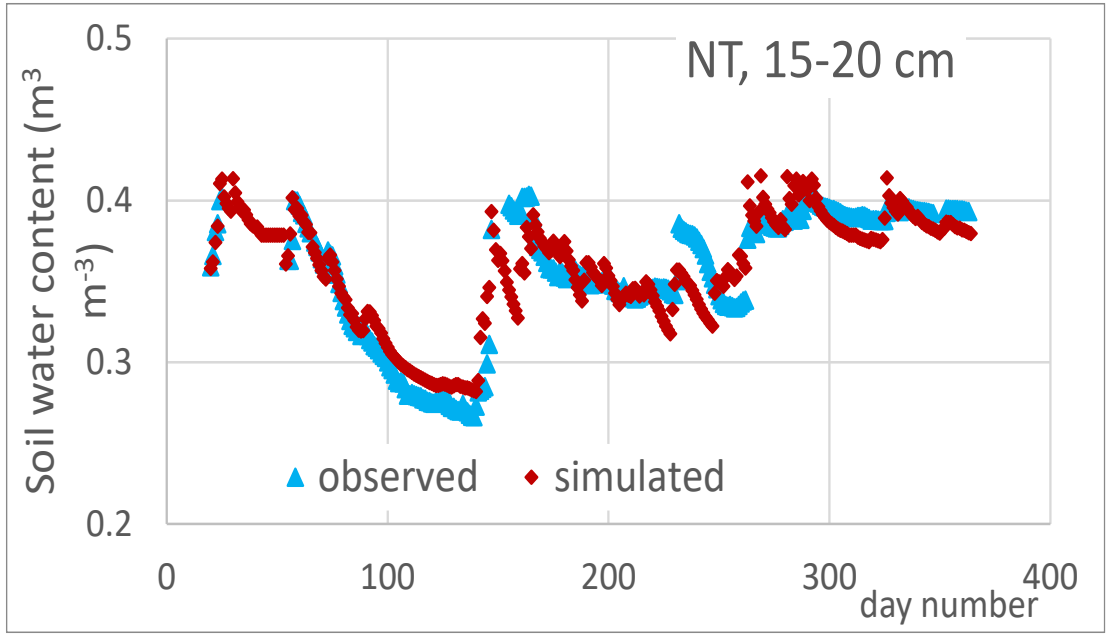
P Ploughing (26–30 cm)
NT No tillage (direct drilling)
D Disking (16–20 cm)
S Shallow cultivator (12–16 cm);
C Cultivator (16–20 cm)
L+D Loosening (35) and Disking (16–20 cm)

Red line – depth of soil tillage

Calibration of the SWAP model for the study area



d = 0.93 (index of agreement)
R^2 = 0.76
NSE = 0.76



d = 0.95 (index of agreement)
R^2 = 0.83
NSE = 0.81

Boundary conditions

- Upper – atmospheric conditions
- Bottom – free drainage from the soil profile

Initial conditions

- Measured soil water content

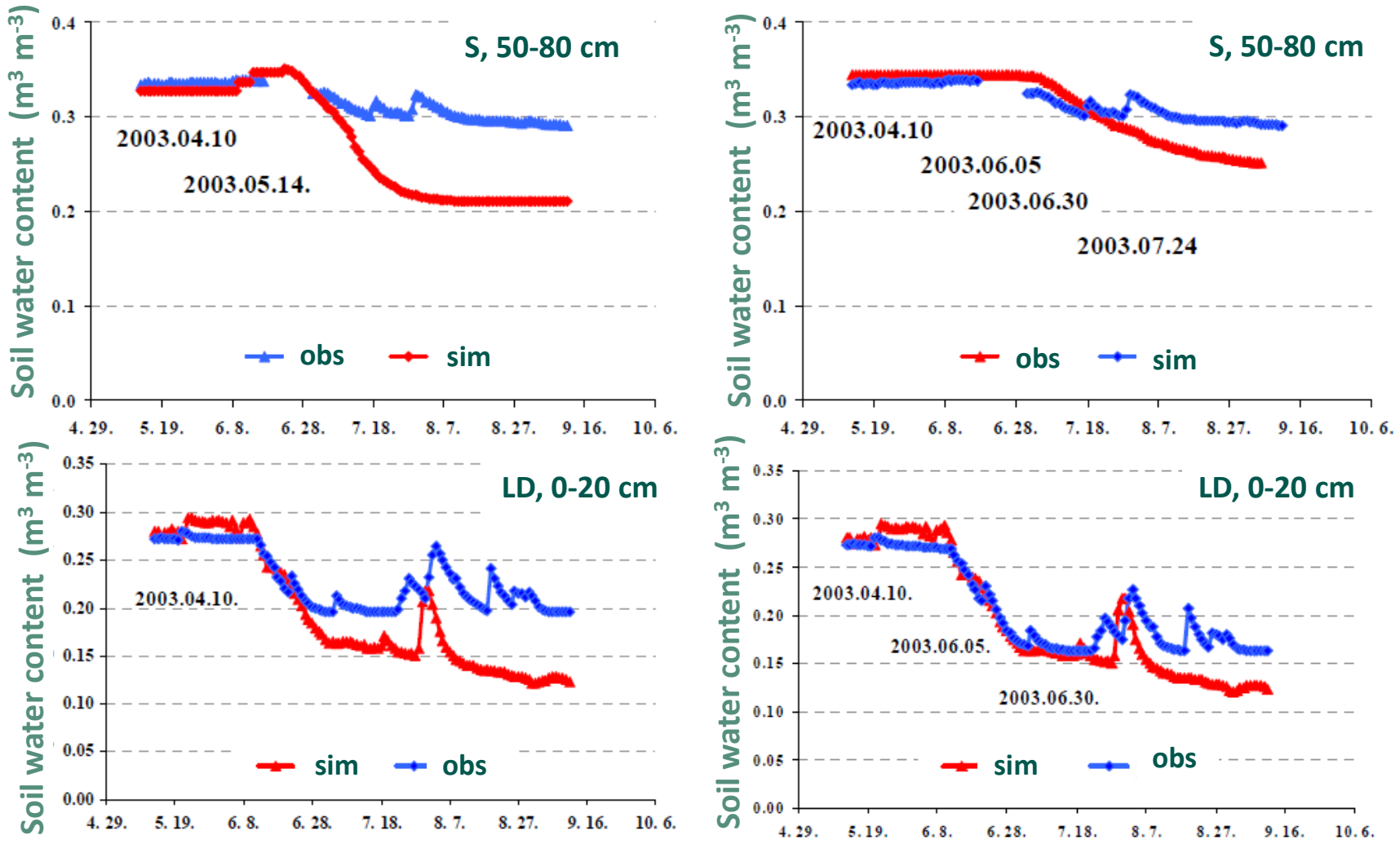
Reference data

- Soil water content monitored in 3 layers

Crop

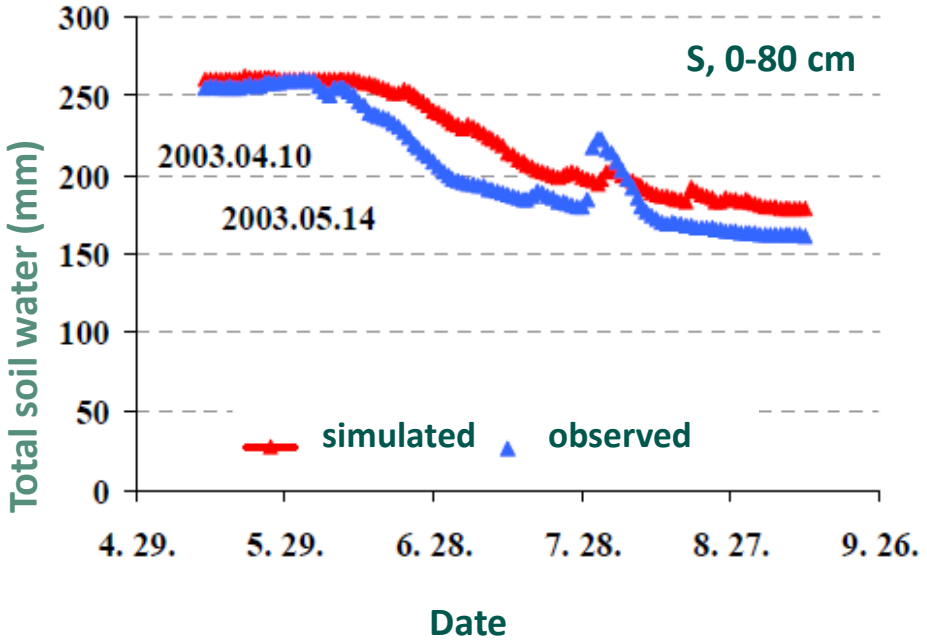
- Simple crop routine, maize, measured crop data

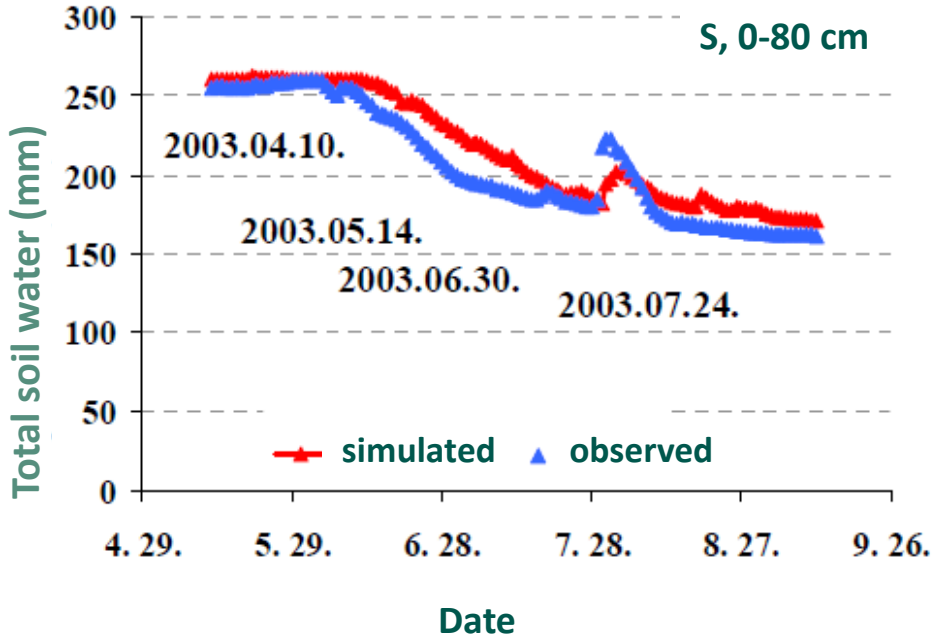
Stepwise validation of the soil water content using temporally variable soil hydraulic properties



Dates next to the curves show the dates
when the soil hydraulic properties were updated in the simulation process

Stepwise calibration of the soil water content using temporally variable soil hydraulic properties





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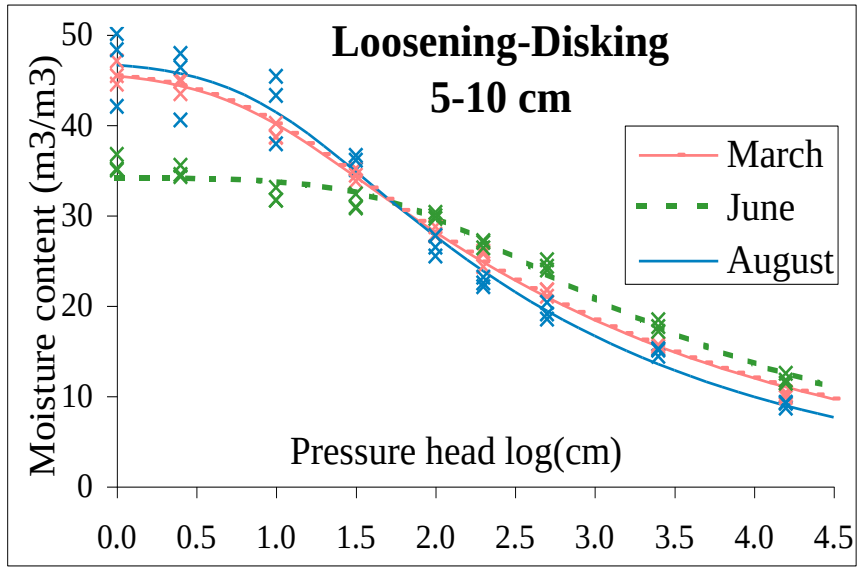
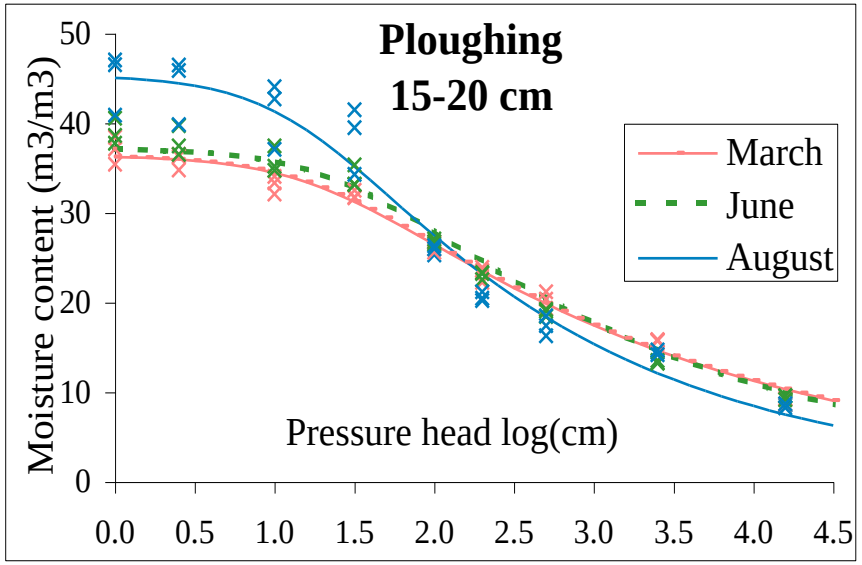
Testing the modified van Genuchten equition





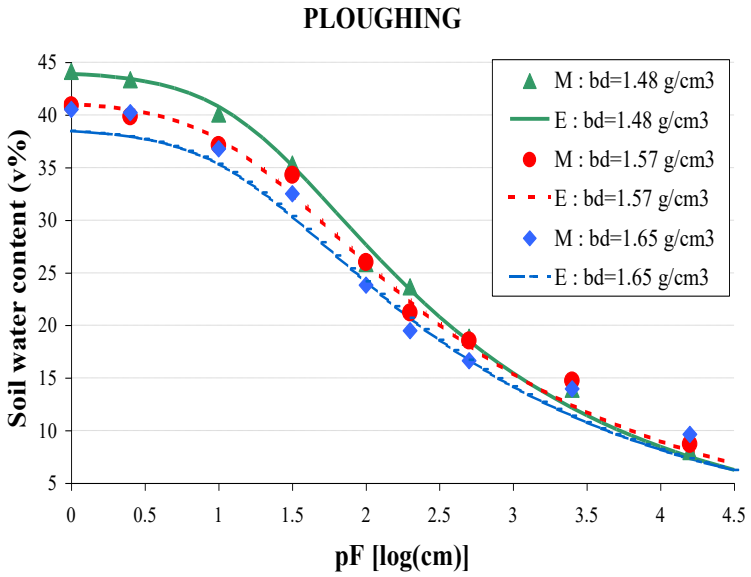
$$\Theta_{pF} = \left(\frac{1}{bd} - \frac{1}{pd}\right)\left[1+(\alpha * \Psi)^{n}\right]^{1/n-1}$$

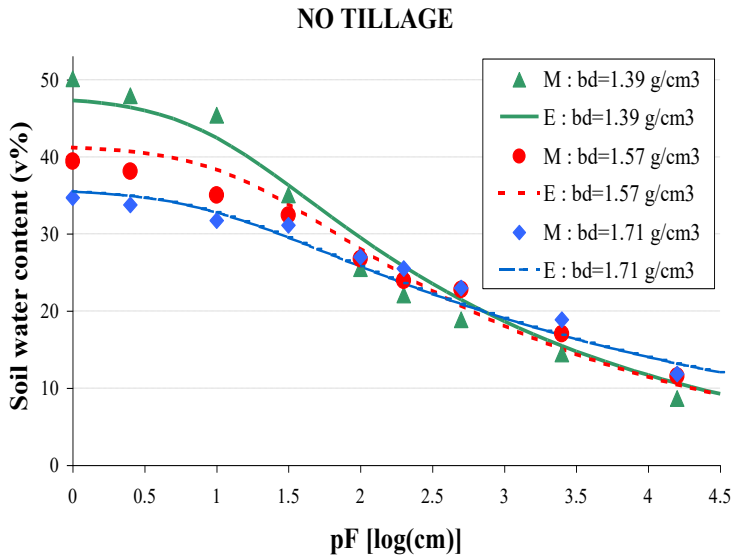
and $n = (\rho_0 - \rho * C)/2$

θ_{pF} - soil water content (g/g)
bd - soil bulk density (g/cm^3)
pd - soil particle density (g/cm^3)
ψ - soil water potential (cm of H_2O)
α - calculated parameter (1/cm)
C - calculated parameter (cm^3/g)

(Sobczuk and Walczak, 1996)

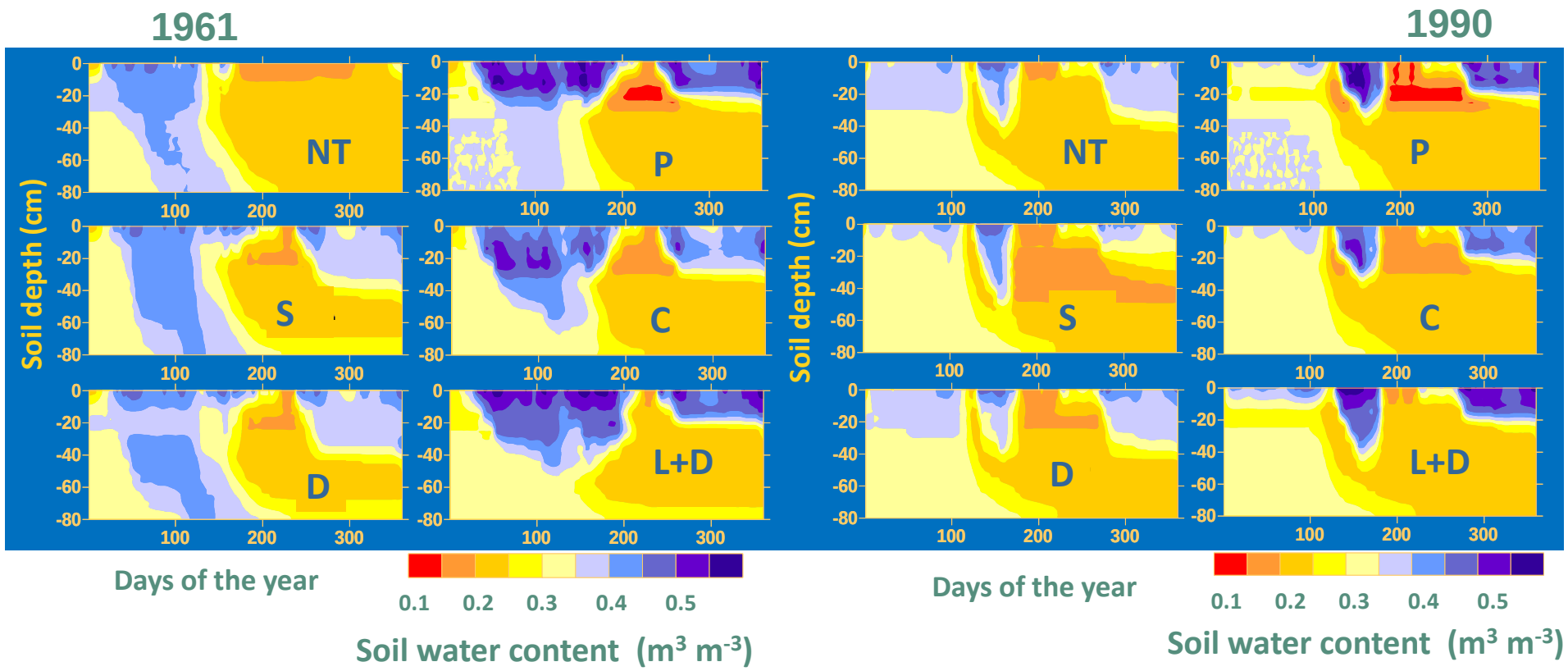
Measured (M) and estimated (E) soil water retention curves for samples with different bulk densities





- ✓ The proposed formula is suitable for estimation of soil water retention curves of tilled soils.
- ✓ Using the Sobczuk-Walcak method, the seasonal variability of the bulk density can be translated into the hydraulic property's variability, avoiding time consuming measurements of the latter ones.

Soil water contents ($m^3\ m^{-3}$), simulated for different soil management practices for two different years of the reference period, representing the present climate



P: Ploughing (26–30 cm)
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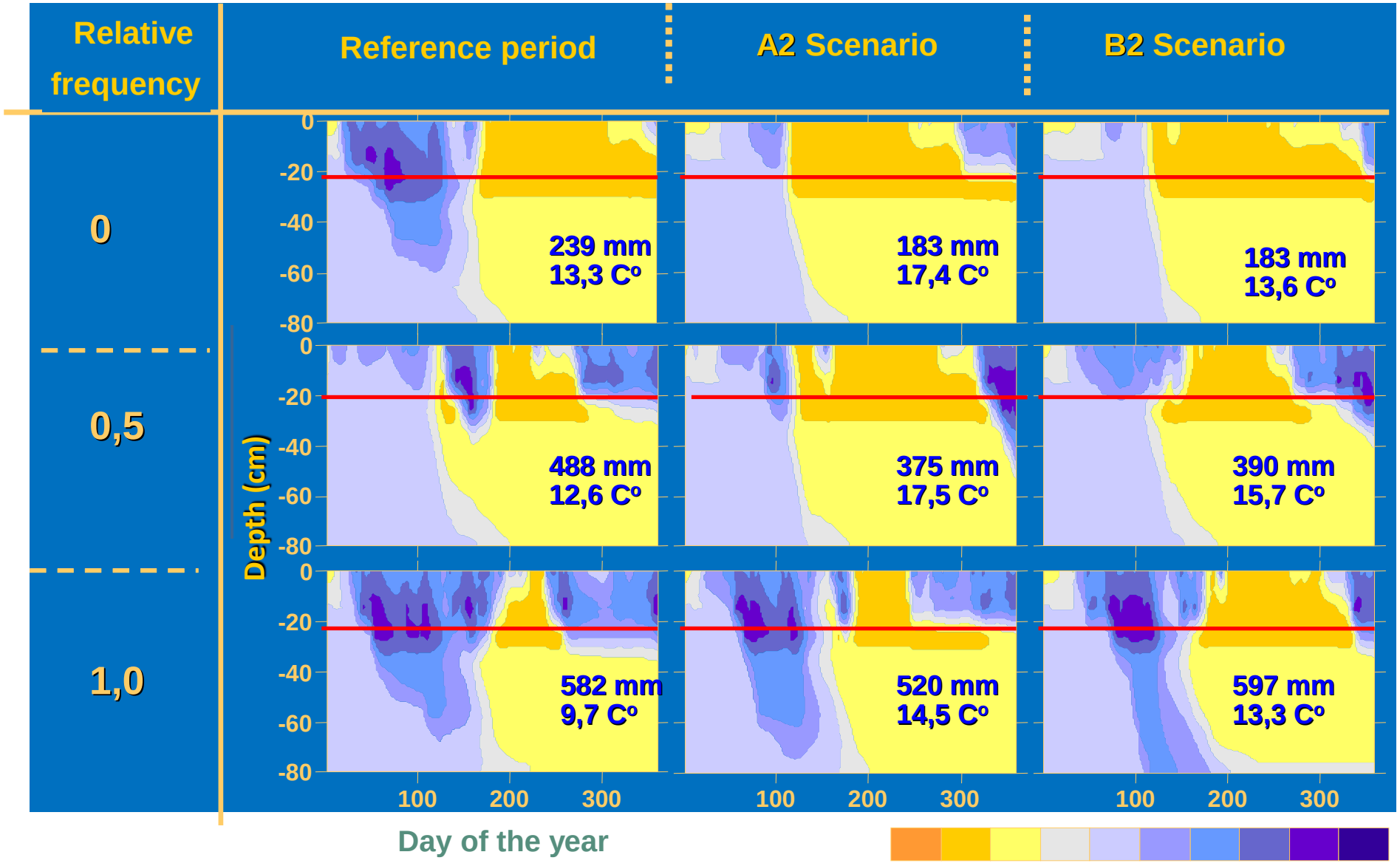
S: Cultivator (12–16 cm)
C: Cultivator (16–20 cm)
L+D: Loosening (35) and Disking (16–20 cm)

Soil water content dynamics, simulated for the cultivator treatment for different scenarios



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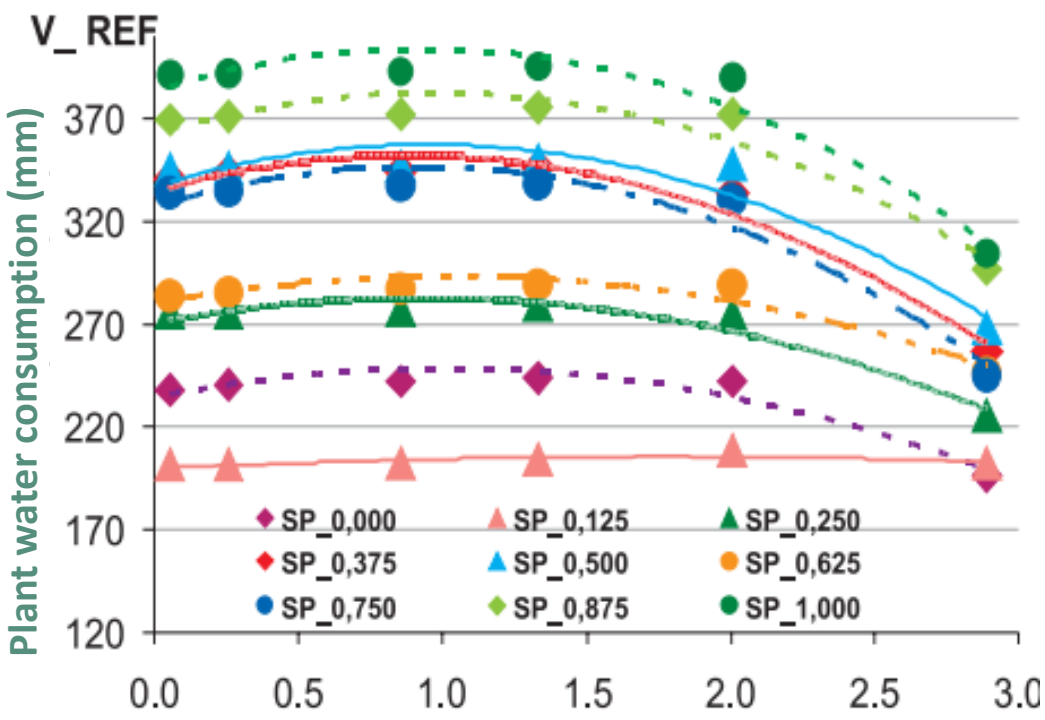
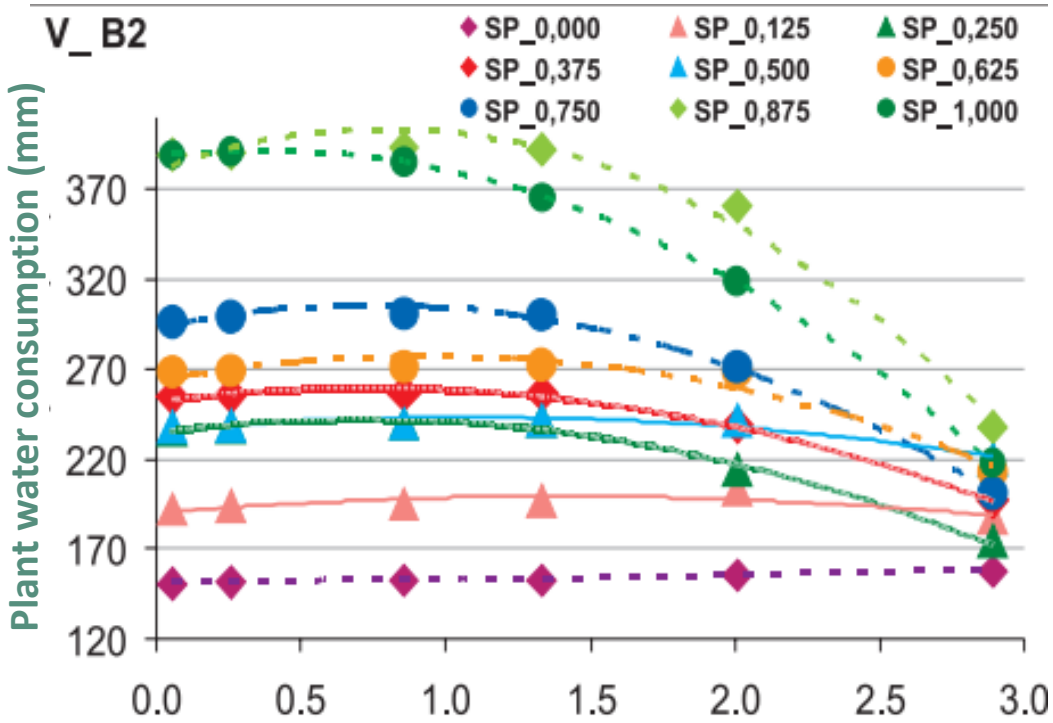
Using the scaling factor for characterising soil water balance elements of different soil types under future climate – water uptake of winter wheat during the vegetation period





Scaling factor, representing spatial variability of soil hydraulic properties

V – Chernosem soil type, loamy texture
V_REF – results for loamy soil for the present – REF – climate
V_B2 – results for loamy soil for the B2 climate scenario

SP – relative frequency of precipitation intensity

Conclusions

- Soil hydraulic functions have **strong seasonal variability** in tilled soils. Its level depends on the level of soil disturbance, rainfall intensity as well as on natural consolidation and **biological activity**
- Incorporation of seasonal changes of soil hydraulic properties in the SWAP soil water balance simulation model improved the simulation results
- Our results indicate that the foreseen harmful effects of the climate change could be mitigated by implementing soil structure and moisture conserving soil management systems
- The modified Van Genuchten equation is a promising method for estimating the temporal variability of soil water retention curve from easily available data
- **We miss the scaling option from the latest model version ☺**

Happy birthday to the SWAP model developers and the whole SWAP community!